Chemically Amplified EUV Resist and Materials Development for 22 nm Half Pitch and Beyond

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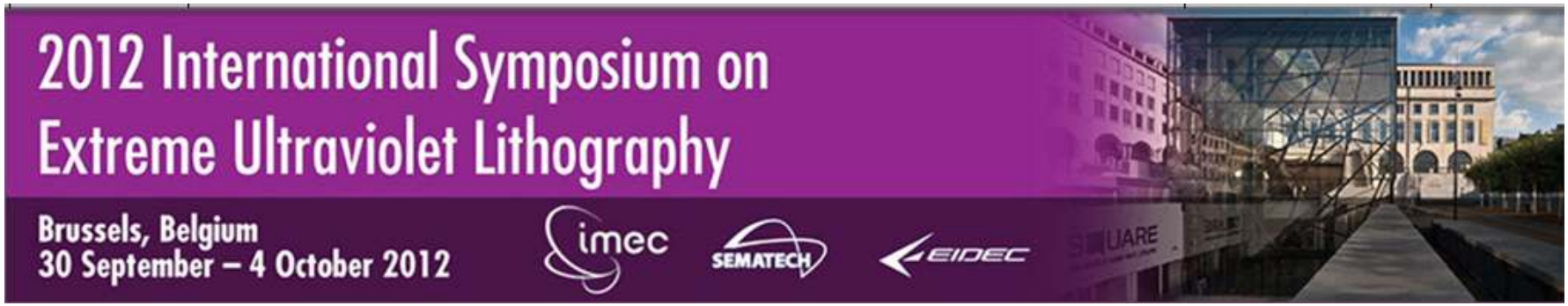
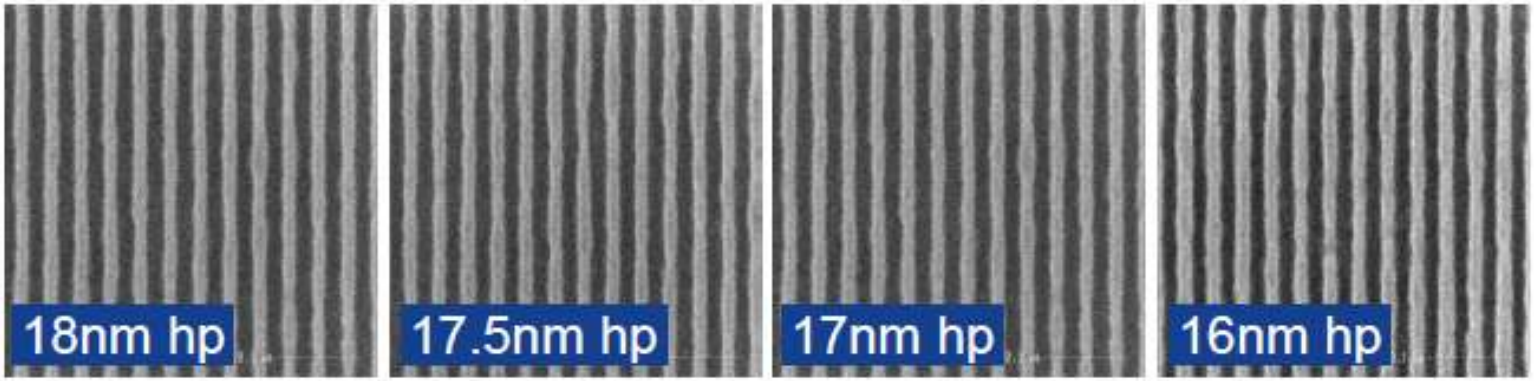
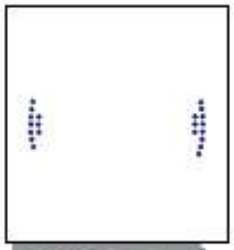


High Resolution Material



All images are single point in the field exposed with dipole-30X at a dose of 33mJ/cm^2 and

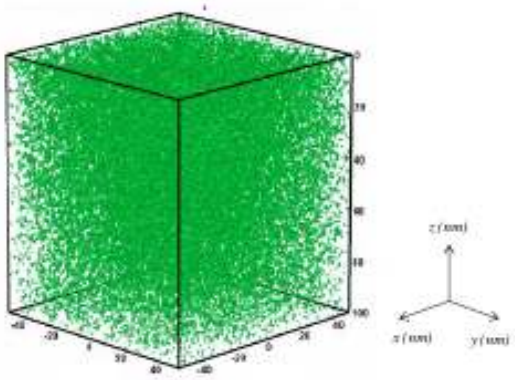


ASML JSR GLOBALFOUNDRIES imec

Ref. Tom Wallow et al, SPIE2012 8322-54

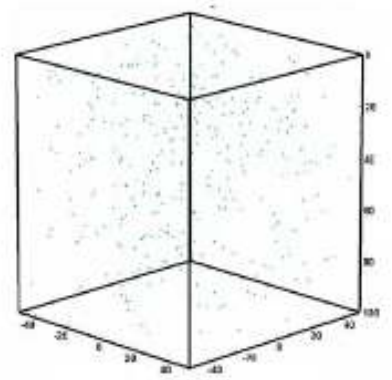
- ***JSR chemically amplified resist (CAR) achieved sub 18 nm hp resolution at LBNL MET***
- ***LWR and Sensitivity improvement is required***

How to design EUV resist



$ArF, 10\,mJ/cm^2, \alpha = A/um$

$n_{absorbed} = 366528,\ E_{absorbed} = 2354\,keV$

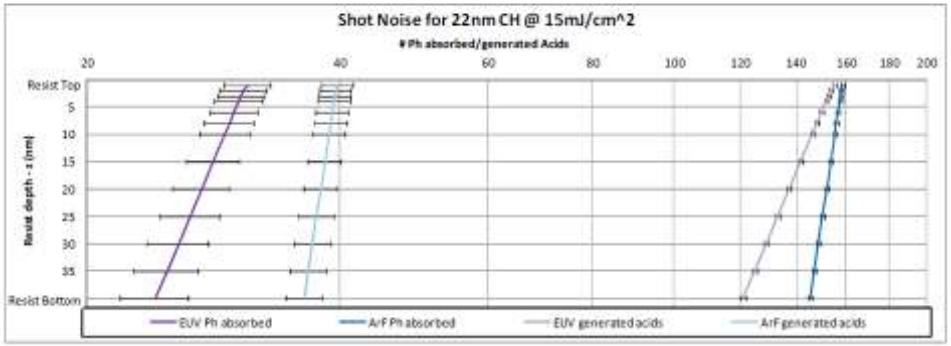


$EUV, 10\,mJ/cm^2, \alpha = A/um$

$n_{absorbed} = 25328,\ E_{absorbed} = 2326\,keV$

Wavelength (nm)	k (α μm^{-1})	QY	Available # Ph/CH area	Available # Ph/nm^2	Ph lost
13.5	0.0068 (6.3)	5.00	4931	~10	78%
193	0.0347 (2.3)	0.25	70488	~146	91%

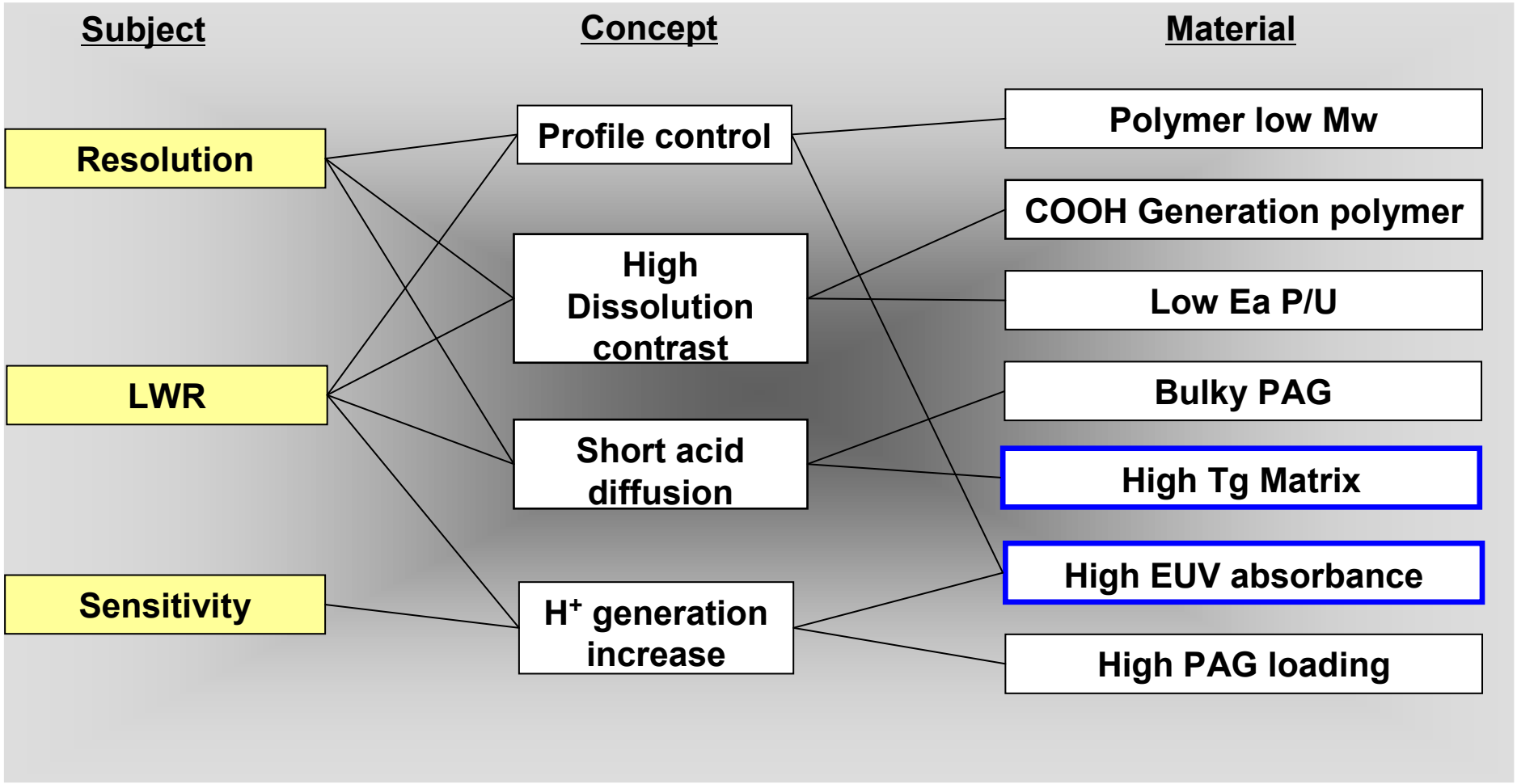
$\alpha = 4\pi * \frac{k}{\lambda}$ $\quad \#Ph = dose * \frac{\lambda}{c * h}$ $\quad Ph_{abs} = Ph_1 * \left(1 - e^{-\alpha t(d)}\right)$ $\quad R^{+}_{gen} = Ph_{abs} * QY$



A. Vaglio Pret, K. Garidis, R. Gronheid, J. Biafore

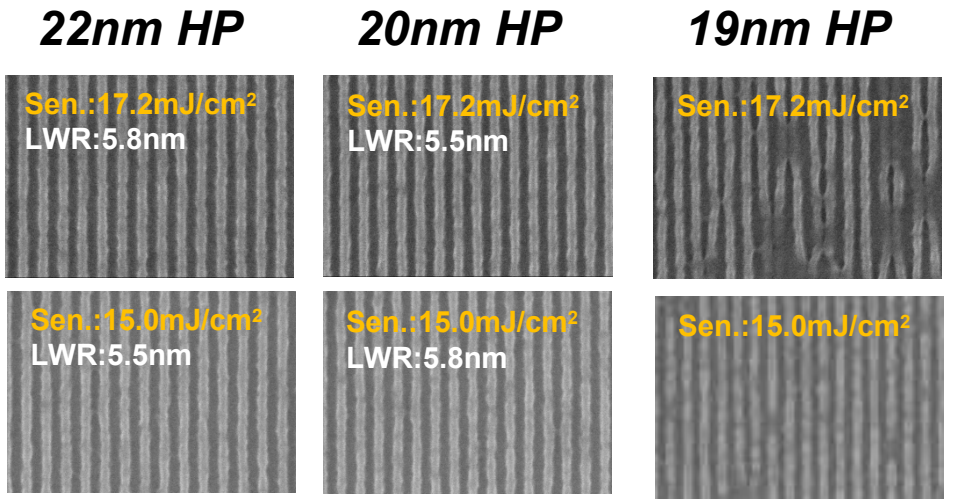
- **Less photons are available for patterning at EUV compared to ArF lithography**
- **EUV resist development should consider materials that use EUV photon effectively in resist design**

High Resolution Resist Design



High Absorbance EUV Resist: RLS Performance

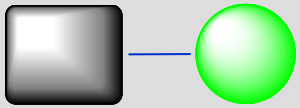
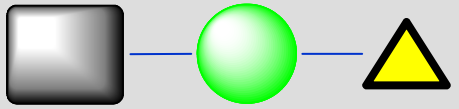
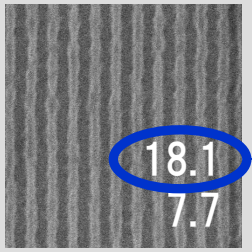
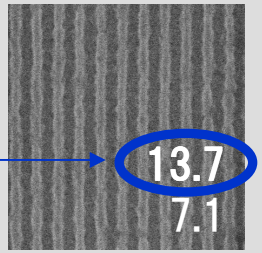
Resin	Absorbance Unit
Low Absorbance	Standard
High Absorbance	25 % Up



LBNL MET, NA0.3, 18nm Dipole

- ***Increasing EUV resin absorbance improves resist sensitivity (13 %)***
- ***Effect of increasing EUV absorbance and absorbance unit was investigated to balance RLS performance***

High Absorbance EUV Resist: Effect of Absorbance Unit

	Standard Resin	Absorbance Resin-A
Polymer Structure		 Applied 3rd unit in polymer
Transparency @13.5nm (calculation, relative)	100	95
Dill's C-parameter	0.04	0.05
Litho performance 26nmLS Eop LWR	 18.1 7.7	 13.7 7.1


Protecting Group


Polar unit

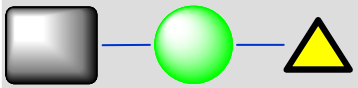
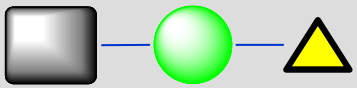
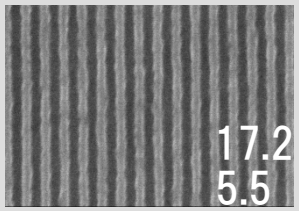
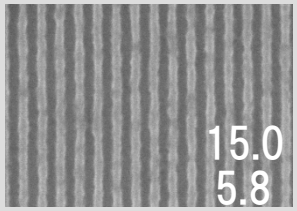

Absorbance Unit

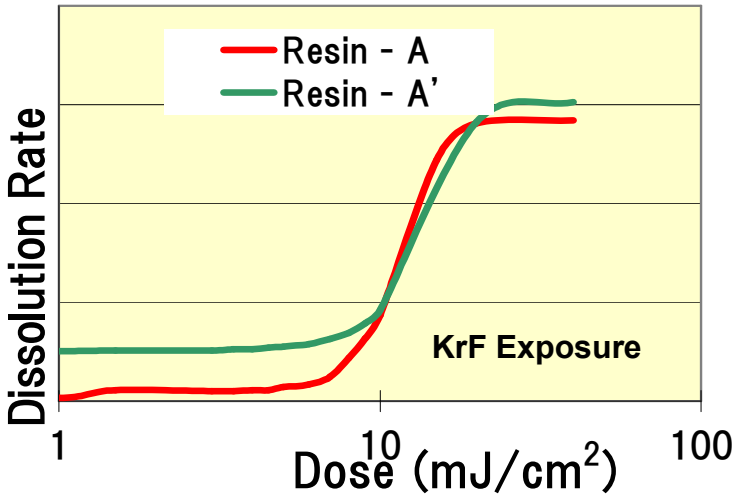
Courtesy of EIDEC

- ***Higher EUV absorbance resist showed higher sensitivity***
- ***High absorbance resist showed higher Dill's C-parameter. It suggests that higher absorbance resin accelerate acid generation***

LWR Mitigation Study: Mole Ratio of Absorbance Unit

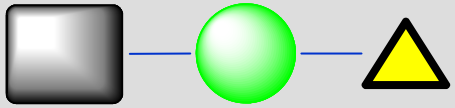
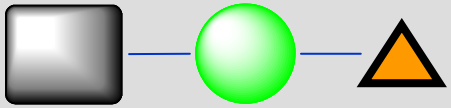
SEMATECH

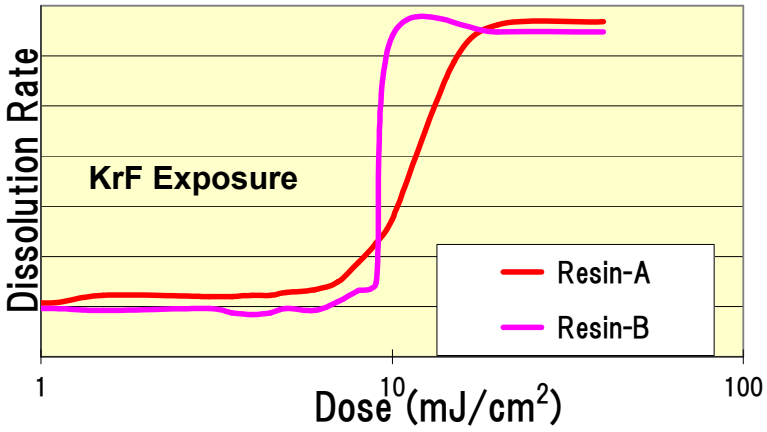
	Absorbance Resin-A	Absorbance Resin-A'
Polymer structure	 Std	 Absorbance unit up
Transparency @13.5nm (calculation, relative)	95	93.5
Dill's C-parameter	0.05	Under analysis
Litho performance 20nmLS Eop LWR		



- ***Resin-A' having higher amount of absorbance unit showed higher absorbance at 13.5nm***
- ***Resin-A' showed higher R_{min}. R_{min} affects dissolution contrast***

New High Absorbance Resin: Control Dissolution Property

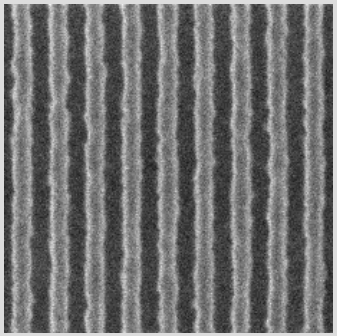
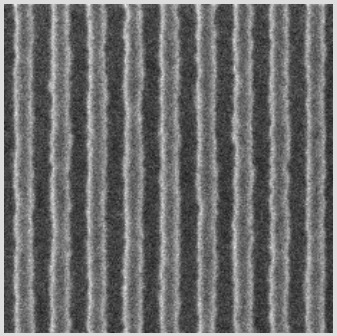
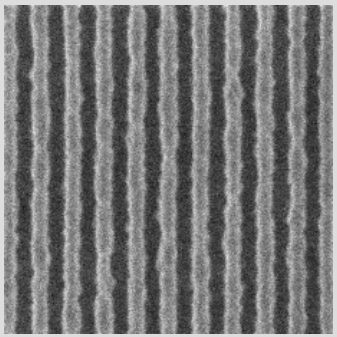
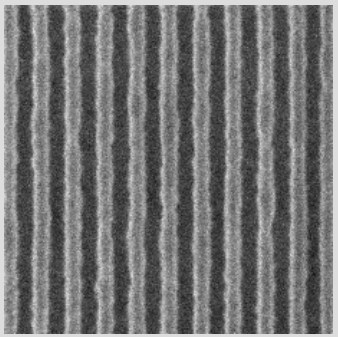
	Absorbance Resin-A	New absorbance Resin-B
Polymer structure		 Applied new 3rd unit
Transparency @13.5nm (calculation, relative)	95	93.5
Tg	std	std + 20deg
Dill's C-parameter	0.05	Under analysis



▲ : New Absorbance Unit

- ***Resin-B with new absorbance unit showed higher Tg and higher absorbance***
- ***Resin-B suppressed R_{min}, and improved dissolution contrast***

New High Absorbance Resist: RLS Performance

	Resin-A	Resin-B
Top view @25nmhp		
Dose to size (mJ/cm2)	11.4	13.4
LER (nm)	4.1	3.4
Top view @22nmhp		
Dose to size (mJ/cm2)	11.0	12.8
LER (nm)	4.4	3.9

imec

NXE3100, NA0.25, Dipole60X

Summary

- ***Sensitivity and LWR improvements are significant challenges for 16 nm hp generation***
  - ***High absorbance resin with different absorbance unit was developed and investigated for 22 nm patterning performance***
  - ***High absorbance resin showed higher absorbance at EUV. Higher Dill's C-parameter for high absorbance resist suggests that high absorbance resin accelerate acid generation***
  - ***Higher absorbance unit affects thermal properties and dissolution contrast***
  - ***EUV resist containing high absorbance resin improved resist sensitivity***
  - ***EUV resist with 2nd generation high absorbance resin achieved balanced RLS performance at 22 nm hp (Es = 12.8 mJ/cm^2; LER = 3.9 nm) on NXE:3100***

Acknowledgment

JSR gratefully thank imec and SEMATECH, for their close collaboration and giving us many evaluation opportunities.

Reference

- Tg measurement => Refraction index measurement

  Reference; ***Brainard, R. L. et al.,*** *Proc. SPIE, 2012, 8322-07*

- Transmittance calculation under 13.5nm wavelength

  Reference; http://www.cxro.lbl.gov/

  CXRO *at Lawrence Berkeley National Laboratory*

- Dill's C parameter => Φacid

  Reference; ***Charles R. Szmanda. et al.,*** *J. Vac. Sci. Technol. B, 1999, 3356*

$$\frac{dP(D)}{dD} = -CP(D) \Rightarrow P(D) = P_0 e^{-CD}$$

$$\Rightarrow A(D) = P_0(1 - e^{-CD}),$$

Thank you for your attention !!

Materials Innovation

JSR

With chemistry, we can.